# *Towards urban resilience through sustainable drainage systems: a multi-objective optimisation problem*

Article

Supplemental Material

## Supplementary materials[1]

This section provides a summary of the key hydrological and hydraulics information used to build the analytical model in this study.

Table 3 – General information

| | |
|---|---|
| Method | Horton |
| Build-up, Wash-off methods | Exponential |
| Min infiltration rate (mm/hr) | 5 |
| Max infiltration rate (mm/hr) | 115 |
| Decay (1/hr) | 6 |
| Evaporation: a time series (mm/day) | 53.41 |

Table 4 – Build-up and wash-off parameters in the Mineirinho catchment

| | Build-up | | | | | | | | | Wash-off | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. buildup (kg/ha) | | | Rate constant | | | Coefficient | | | Exponent | | | Cleaning efficiency % | | | BMP efficiency % | | |
| **Land-use** | **TSS** | **TP** | **TN** | **TSS** | **P** | **TN** | **TSS** | **P** | **TN** | **TSS** | **P** | **TN** | **TSS** | **P** | **TN** | **TSS** | **P** | **TN** |
| **AGR*** | 337.96 | 0.00230 | 0.30 | 0.30 | 0.011 | 0.12 | 12.58 | 3.16 | 26.880 | 2.98 | 0.80 | 3.78 | 50 | 50 | 50 | 20 | 20 | 20 |
| **CGA*** | 37.54 | 0.00013 | 0.30 | 2.09 | 0.036 | 0.47 | 7.68 | 4.78 | 7.940 | 7.78 | 4.77 | 7.18 | 50 | 50 | 50 | 20 | 20 | 20 |
| **COM*** | 380.72 | 0.04900 | 0.26 | 0.32 | 0.011 | 0.23 | 11.24 | 0.77 | 25.690 | 4.54 | 0.51 | 5.32 | 50 | 50 | 50 | 20 | 20 | 20 |
| **FRS*** | 14.39 | 0.00011 | 0.22 | 0.58 | 0.018 | 0.19 | 3.54 | 2.37 | 4.250 | 5.37 | 1.38 | 5.40 | 50 | 50 | 50 | 20 | 20 | 20 |
| **IND*** | 448.91 | 0.05800 | 0.36 | 0.59 | 0.019 | 0.56 | 15.18 | 1.01 | 54.210 | 6.28 | 0.67 | 8.89 | 50 | 50 | 50 | 20 | 20 | 20 |
| **OPS*** | 214.87 | 0.00650 | 0.19 | 0.35 | 0.031 | 0.18 | 7.92 | 2.98 | 28.295 | 1.73 | 1.00 | 2.70 | 50 | 50 | 50 | 20 | 20 | 20 |
| **PNS*** | 18.77 | 0.00007 | 0.15 | 1.05 | 0.018 | 0.24 | 3.84 | 2.39 | 3.970 | 3.89 | 2.39 | 3.59 | 50 | 50 | 50 | 20 | 20 | 20 |
| **RDS*** | 117.29 | 0.00300 | 0.03 | 1.55 | 0.120 | 0.51 | 5.46 | 4.73 | 37.010 | 5.52 | 2.92 | 5.51 | 50 | 50 | 50 | 20 | 20 | 20 |
| **RGA*** | 37.54 | 0.00013 | 0.30 | 2.09 | 0.036 | 0.47 | 7.68 | 4.78 | 7.940 | 7.78 | 4.77 | 7.18 | 50 | 50 | 50 | 20 | 20 | 20 |
| **RSD*** | 18.00 | 0.03100 | 0.36 | 0.30 | 0.200 | 0.60 | 9.59 | 2.00 | 13.240 | 5.49 | 4.16 | 3.59 | 50 | 50 | 50 | 20 | 20 | 20 |

*AGR: Agriculture; CGA: Commercial Grass area; COM: Commercial; FRS: Forest; IND: Industrial; OPS: Open Space; PNS: Pines; RDS: Roads; RGA: Residential Grass area; RSD: Residential

Table 5 – GNR design parameters

| Surface | | Soil | | Drainage mat/layer | |
|---|---|---|---|---|---|
| Berm height (mm) | 30 | Thickness (mm) | 50 | Thickness (mm) | 3 |
| Vegetation volume fraction | 0.1 | Porosity (volume fraction) | 0.5 | Void fraction | 0.5 |
| Surface roughness (Manning's n) | 0.1 | Field Capacity (volume fraction) | 0.2 | Roughness (Manning's n) | 0.1 |
| Surface slope (%) | 1 | Wilting point (volume fraction) | 0.1 | | |
| | | Seepage rate (mm/hr) | 0.5 | | |
| | | Conductivity slope | 10 | | |
| | | Suction head (mm) | 3.5 | | |



[1] Journal of Environmental Management, Vol 275, 1 December 2020, 111173 - https://doi.org/10.1016/j.jenvman.2020.111173

Table 6 – RNB design parameters

| | |
|---|---|
| Storage depth (mm) | 1000 |
| Flow efficiency (mm/hr) | 1 |
| Flow exponent | 0.5 |
| Offset height (mm) | 6 |
| Drain delay (hr) | 6 |

Table 7 – GSW design parameters

| | |
|---|---|
| Berm height (mm) | 600 |
| Width (top, bottom) (m) | (3.0,1.0) |
| Vegetation volume fraction | 0.3 |
| Surface roughness (Manning's n) | 0.368 |
| Channel slope* (%) | 7 |
| Swale side slope (run/rise) | 1:1 |

* the average slope of sub-catchments within the Mineirinho Catchment

Table 8 – PVP design parameters

| **Surface** | | **Soil** | | **Pavement** | | **Storage** | | **Drain** | |
|---|---|---|---|---|---|---|---|---|---|
| Berm height (mm) | 200 | Thickness (mm) | 500 | Thickness (mm) | 150 | Thickness (mm) | 600 | Flow efficiency (mm/hr) | 0 |
| Vegetation volume fraction | 0.1 | Porosity (volume fraction) | 0.5 | Void ratio (voids/solids) | 0.15 | Void ratio (voids/solids) | 0.74 | Flow exponent | 0.5 |
| Surface roughness (Manning's n) | 0.1 | Field capacity (volume fraction) | 0.2 | Impervious surface fraction | 0 | Seepage rate (mm/hr) | 0.5 | Offset height (mm) | 6 |
| Surface slope (%) | 7 | Wilting point (volume fraction) | 0.1 | Permeability (mm/hr) | 100 | Clogging factor | 0 | | |
| | | Seepage rate (mm/hr) | 0.5 | Clogging factor | 0 | | | | |
| | | Conductivity slope | 10 | | | | | | |
| | | Suction head (mm) | 3.5 | | | | | | |

Table 9 – BIR design parameters in the Mineirinho catchment

| **Surface** | | **Soil** | | **Storage** | | **Drain** | |
|---|---|---|---|---|---|---|---|
| Berm height (mm) | 300 | Thickness (mm) | 500 | Thickness (mm) | 2700 | Flow efficiency (mm/hr) | 0 |
| Vegetation volume fraction | 0.1 | Porosity (volume fraction) | 0.5 | Void ratio (voids/solids) | 0.75 | Flow exponent | 0.5 |
| Surface roughness (Manning's n) | 0.1 | Field capacity (volume fraction) | 0.2 | Seepage rate (mm/hr) | 0.5 | Offset height (mm) | 6 |
| Surface slope (%) | 5 | Wilting point (volume fraction) | 0.1 | Clogging factor | 0 | | |
| | | Seepage rate (mm/hr) | 0.5 | | | | |

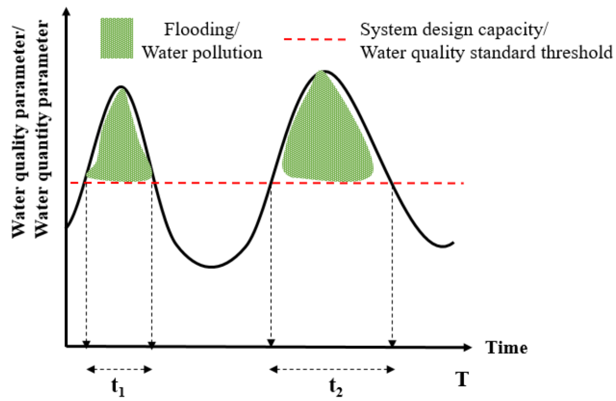


Fig. 1. Hypothetical flood resilience curve represents the excessive water beyond the design capacity of the drainage network over time; hypothetical water quality resilience curve demonstrates the violation of water quality from the defined water quality standards over time

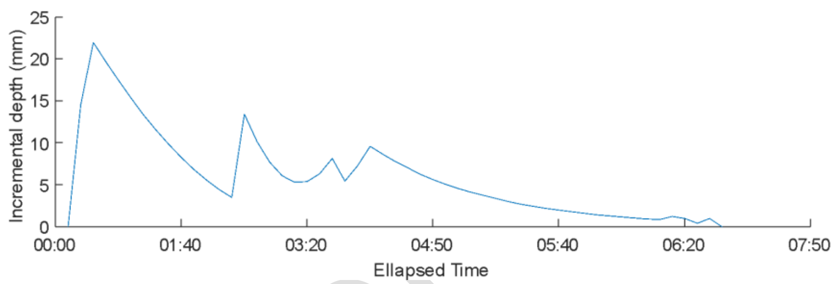


Fig. 2. The two-stage design storm rainfall pattern using Huff Heavy Storm equations